SANTANA

Compact Narrow-Linewidth Laser Sources for Optical Atomic Clocks

Optical atomic clocks require laser sources with exceptional spectral precision and stability. For wider deployment, these sources must also become more compact, robust and cost-effective to manufacture. The German-British SANTANA collaborative research project is developing a miniaturised laser module that combines semiconductor laser technology with photonic integrated circuits. Sacher Lasertechnik is undertaking key development work on the laser chip, optical coupling and precision assembly processes.

Project at a glance

- **Project title:** Small External Cavity Narrow Linewidth Laser
- **Acronym:** SANTANA
- **Project partners:** Sacher Lasertechnik, Technische Universität Berlin, National Physical Laboratory and Bay Photonics
- **International collaboration:** Germany and the United Kingdom
- **Funding programme:** Central Innovation Programme for SMEs (ZIM), with UK partner funding through Innovate UK
- **Funding reference:** 16KN102220

Objectives and Approach

SANTANA aims to develop a compact laser source for the next generation of optical atomic clocks. These clocks offer potential for precise timekeeping and synchronisation in applications such as navigation, communication networks and quantum technologies. Deployment outside specialised laboratories, however, requires substantial reductions in size, weight, power consumption and cost.

The project is therefore developing a hybrid-integrated external cavity diode laser. A semiconductor laser chip is coupled to a silicon nitride photonic integrated circuit, or PIC. The PIC combines a ring resonator with a Bragg grating and feeds a narrow spectral portion of the light back into the laser chip. This frequency-selective feedback is intended to enable an exceptionally narrow linewidth.

For strontium applications, the targets are a central wavelength of approximately 689 nanometres, a linewidth below 500 hertz, an output power exceeding 50 milliwatts and a tuning range greater than two gigahertz.

Sacher Lasertechnik's Contribution

Sacher Lasertechnik is developing suitable semiconductor gain chips and working with the National Physical Laboratory on the photonic cavity concept. Curved output waveguides and tailored facet coatings are intended to reduce unwanted reflections and support controlled coupling between the laser chip and PIC.

Another focus is precision component assembly. Soldering, adhesive bonding and alignment processes with submicrometre accuracy are being investigated and qualified. The objective is a mechanically and thermally stable assembly that can be manufactured reproducibly.

Together with Technische Universität Berlin, solutions are also being developed for fibre coupling and integration into a compact butterfly package. The laser module is intended to feature a polarisation-

maintaining output fibre. Assembly processes suitable for automation are intended to prepare for subsequent scaling to higher production volumes.

Expected Results and Outlook

The consortium aims to develop a compact, user-friendly laser system, which Bay Photonics will complement with drive electronics and additional optical functions. The National Physical Laboratory will characterise the systems and test them with an optical atomic clock. Additional temperature-cycling and vibration tests will assess their robustness.

SANTANA thus establishes a foundation for transforming high-precision laser sources from complex laboratory setups into integrated modules. Beyond optical atomic clocks, the laser and assembly concepts developed offer potential for cold-atom sensing, precision spectroscopy and other quantum technologies. Sacher Lasertechnik plans to further develop the laser module both as a system component and as a standalone product.